

# Damage reduction to ponderosa pine seedlings from northern pocket gophers by vegetation management through grass seeding and herbicide treatment

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## Abstract

2,4-D herbicide treatment was applied to 2 treatment units to remove the forbs that are the preferred food of pocket gophers. One of these units also was seeded with grasses prior to the 2,4-D treatment. The effect of 2,4-D and grass seeding plus 2,4-D treatments were compared to an untreated control unit. Long-term monitoring (7 yr) was conducted on the 3 units for vegetative cover (7 yr), pocket gopher activity, and individual survival times and time until gopher damage for 2 cohorts of seedlings (5 and 6 yrs). The 2,4-D treatments greatly reduced vegetative cover of the forbs and seeding increased grass cover on the unit receiving that treatment. Pocket gopher activity was reduced somewhat on the unit receiving only the 2,4-D treatment and more so on the unit receiving grass seeding and 2,4-D, although gophers remained active to some degree throughout the study. Both cohorts of seedlings for both treatments units showed greater average times until gopher damage over seedlings on the control unit. However, seedling survival from all sources of mortality was not positively affected by the treatments for the first cohort of seedlings. The 2,4-D treatment appeared to have killed some of the seedlings; however, seedlings that survived the treatment were in a situation where they were less likely to be damaged by gophers and seemed to have improved growth rates. Published by Elsevier Science Ltd.

## 1. Introduction

Pocket gophers (*Thomomys* spp.) are responsible for considerable damage to reforestation efforts in the Pacific Northwest (e.g., Barnes, 1973; Crouch, 1986). Damage reduction has usually involved the use of trapping or rodenticides to control pocket gopher populations (e.g., Crouch and Franks, 1979), but this often achieves only short-term control as populations can recover very quickly (Campbell et al., 1992; Sullivan, 1986), making repeated applications necessary. Besides these cost-efficacy issues, there is an increasing interest in the use of non-lethal means to reduce animal damage (Acord, 1992), and a variety of non-lethal strategies are being investigated for reducing pocket gopher damage to reforestation projects (Engeman et al., 1995a).

Previous studies have demonstrated quick reductions in pocket gopher food resources through herbicide treatments, with an associated decline in pocket gopher population indices. Keith et al. (1959) in Colorado and Hull

(1971) in Idaho reported reduced pocket gopher abundance in rangelands after 2,4-D treatment. Increased seedling stocking rates have been reported following herbicide treatment. Cristensen et al. (1974) described a reduction in competing plants through atrazine treatments that resulted in improved stocking rates of ponderosa pine seedlings. Crouch and Hafenstein (1977) described an enhanced seedling-establishment environment through atrazine treatment and an associated improvement in ponderosa pine seedling stocking rates. They hypothesized that the improvement in stocking rate also may have been due to an associated reduction in pocket gopher populations. Crouch (1979) further described improved long-term seedling survival rates and diminished gopher activity on the series of 0.04 ha plots that received atrazine treatments. Black and Hooven (1977), using 3 herbicide treatments, demonstrated much improved seedling survival for 5 species of conifer from the use of combinations of herbicides including atrazine, simazine and 2,4-D. More recently, Engeman et al. (1995b) described how an atrazine treatment produced long-term reductions in Mazama pocket gopher (*Thomomys mazama*) forage and populations, with a cor-

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responding substantial increases in survival of ponderosa pine seedlings (*Pinus ponderosa*). This paper presents long-term results from using a 2,4-D herbicide treatment and a 2,4-D treatment after seeding with grasses to reduce pocket gopher populations, and subsequently damage, by limiting their food resources in both cases and also establishing less preferred plants in one case.

## 2. Methods

The study was conducted on the Bear Springs timber sale in the Deschutes National Forest, Oregon. The vegetation community on the study site primarily was a mixed conifer-snowberry (*Symphoricarpus albus*)-pine-grass (*Calamagrostis rubescens*) community (Volland, 1976). White fir (*Abies concolor*), Douglas fir (*Pseudotsuga menziesii*), and ponderosa pine dominated the mature overstory. Northern pocket gophers (*Thomomys talpoides*) were distributed throughout the area, with greatest abundance in forest openings. Timber on the study site had been harvested 2 years prior to the initiation of the study (June 1971).

Within this area, 3 study units of 2.8 to 4 ha were identified for study. One unit was randomly selected to receive herbicide treatment with 2,4-D at a rate of 2.3 kg acid equivalent in 187.5 L water carrier per ha to eliminate the forbs, which are the preferred food of the pocket gophers. Another unit was selected to be seeded with grasses prior to 2,4-D treatment. The third unit served as an untreated control. Although the proximity, similarity, and pretreatment vegetation provided reasonable assurances that differences in response between these units would be due to treatment effects, confirmation with additional units would be highly desirable to provide more general inferences.

Grasses were seeded at a rate of 1.5–1.8 kg/ha in November of 1972 and fertilized the same month. The grass mixture included Timothy (*Phleum pratense*) (10%), smooth brome (*Bromus inermis*) (30%), hard fescue (*Festuca ovina duriuscula*) (10%), orchardgrass (*Dactylis glomerata*) (30%), and intermediate wheatgrass (*Agropyron intermedium*) (20%). In April of 1973 the sale area, including the 3 study units, were operationally planted at a stocking rate of approximately 1000 trees/ha with ponderosa pine seedlings that had been nursery grown for 2 years. We applied 2,4-D treatment using a boom rig on a tractor in June of 1973 and spot treatments were applied where needed in June 1974 using backpack apparatus to avoid seedlings.

Pocket gopher activity was also monitored pre- and post-treatment. Ten transects, each 60 m long were randomly located in each of the 3 units. We established 3 81 m<sup>2</sup> circular plots with their center points 20 m apart along each transect to monitor gopher activity. Mound counts (Anthony and Barnes, 1984) were used to assess

activity. We erased all gopher sign and 48 hrs later gopher sign produced in the intervening time would be counted. A plot was classified as active if any gopher sign was detected. Pocket gopher activity was monitored each August from 1972 through 1978.

We measured vegetation prior to treatment in each unit so that herbicide treatment and seeding efficacy on the plant community could be verified. Five plots, 20 cm × 50 cm, were located between the first 2 pocket gopher activity plots on each transect. As in past studies (Engeman et al., 1995b; Engeman et al., 1997) percent canopy cover was measured using the Daubenmire technique (Daubenmire, 1959) for grasses, forbs and shrubs at the end of the summer of 1972 (prior to seeding with grasses) and twice each summer (early, late) from 1973 through 1978. (A complete listing of the 79 plant species observed on the study area is available from the first author.)

We monitored seedlings along 10 lines, with 25 seedlings per line, established parallel to the activity-/vegetative transects. A second planting of seedlings was done in May of 1974 to replace the seedlings from the first planting that had not survived. These new trees were considered as a second cohort for study. Each seedling was monitored for survival, cause of death, and time until first gopher damage. Seedling heights were measured in 1976, 1977, and 1978.

We compared pocket gopher activity measurements between the treated and control units each year by applying Pearson's chi-square to the 2 × 3 contingency table data. We analyzed time until first gopher damage and survival time using Kaplan and Meier (1958) survival analyses and Wilcoxon comparisons of survival curves (Kalbfleish and Prentice, 1980). Seedling growth in height was compared among treatments using 1-way ANOVAs for each cohort (1973 and 1974 plantings).

## 3. Results

The 2,4-D treatments greatly reduced forbs on the treated units (Table 1). Note that the 2,4-D treatment unit initially had more grass cover than either of the other 2 units. By the end of the study, however, the unit which had grasses planted in addition to the 2,4-D treatment had the greatest grass cover, 50% more than on the 2,4-D unit. By the end of the study, the control unit began to approach the 2,4-D unit in grass cover. Shrubs were not very abundant to begin with and, therefore, probably did not play an important role in reducing gopher activity.

A comparison of the treated and control units in 1972, prior to treatment, indicated initial differences in pocket gopher activity among the 3 units (Table 2), with the 2,4-D unit having the greatest activity (63.33%), the control unit having next most (30.00%), and grass plus 2,4-D

Table 1

Percent canopy cover for forbs, grasses, and shrubs from 1974 through 1979 on the control, 2,4-D treated, and 2,4-D + grass treated units in Deschutes National Forest, Oregon

Year	Time	Forbs			Grasses			Shrubs		
		Control	2,4-D	2,4-D + grass	Control	2,4-D	2,4-D + grass	Control	2,4-D	2,4-D + grass
1972	Late	7.65	12.50	2.40	0.15	3.50	0.00	1.05	0.95	1.10
1973	Early	15.90	7.70	4.07	0.45	8.65	0.36	1.60	2.30	2.21
	Late	16.60	3.15	2.43	0.70	7.15	0.57	2.50	0.10	0.57
1974	Early	9.45	1.20	1.35	2.15	8.80	2.42	3.35	0.05	2.00
	Late	9.85	1.50	0.92	2.15	9.25	3.49	4.55	0.00	0.94
1975	Early	17.20	1.35	2.07	4.70	15.10	10.10	6.70	0.00	0.50
	Late	26.00	3.00	5.14	4.45	10.30	9.79	7.00	0.05	0.64
1976	Early	20.80	2.20	3.64	8.15	12.80	19.50	6.30	0.05	2.36
	Late	23.80	3.15	7.79	0.60	16.80	25.80	8.20	0.05	2.79
1977	Early	21.60	4.00	5.80	11.90	14.00	34.30	7.60	0.05	2.21
	Late	22.80	6.80	5.64	12.60	19.70	28.30	7.70	0.05	3.14
1978	Early	25.00	9.90	4.28	27.60	30.80	45.10	8.45	0.00	3.14
	Late	23.50	9.45	6.85	19.00	30.00	49.40	9.15	0.00	4.85

unit having the least (9.52%). In the years after treatment, the control unit had the most activity, although in 1977 the 2,4-D unit had 60.00% versus 56.67% for the control. Activity on the grass plus 2,4-D unit approached the levels on the 2,4-D unit in some years, but generally remained slightly less. Most importantly, ample pocket gopher activity occurred on the 2 treatment units, with differences in activity from the control unit not statistically distinguishable for about half of the years (Table 2).

The time until a seedling in the 1973 cohort was attacked by a gopher was similar for the 2,4-D and the 2,4-D plus grass treatments, but seedlings on the control unit exhibited a shorter average time until gopher damage (Table 3), resulting in pronounced differences among survival curves (Fig. 1) (Wilcoxon comparison of Kaplan–Meier survival curves;  $\chi^2 = 24.48$ ,  $df = 2$ ,  $p < 0.0001$ ). In the 1974 cohort, the three survival curves were distinct (Fig. 2), with seedlings in the 2,4-D plus grass treatment not receiving damage as soon as those in the 2,4-D treatment, and both treatments receiving damage at a lesser

Table 3

Mean times (days) until pocket gopher damage and mean survival times for two cohorts of seedlings on each of three experimental unit in Deschutes National Forest, Oregon

Cohort	Unit	Time until gopher damage		Survival time	
		$\bar{x}$	S.E.	$\bar{x}$	S.E.
1973	2,4-D	1490	50	927	48
	2,4-D + grass	1517	60	1002	61
	Control	1172	47	1175	48
1974	2,4-D	1103	55	880	56
	2,4-D + grass	1394	53	1151	69
	Control	683	67	517	50

rate than the control seedlings (Table 3). Again, differences resulted among treatment survival curves (Wilcoxon comparison of Kaplan–Meier survival curves;  $\chi^2 = 45.57$ ,  $df = 2$ ,  $p < 0.0001$ ).

The overall survival time of seedlings from mortality

Table 2

Percent of activity plots with positive readings on 1 control and 2 treated units in Deschutes National Forest, Oregon and the results of Pearson's chi-square test for differences among treatments in the proportion of plots active

Year	2,4-D % Active	2,4-D grass % Active	Control % Active	$\chi^2$ (2 df)	$p$
1972	63.33	9.52	30.00	16.350	<0.001
1973	73.33	42.86	83.33	9.878	0.007
1974	46.67	47.62	73.33	5.319	0.070
1975	56.67	42.86	80.00	7.730	0.021
1976	66.67	61.90	73.33	0.774	0.679
1977	60.00	23.81	56.67	7.484	0.024
1978	46.67	33.33	60.00	3.560	0.169

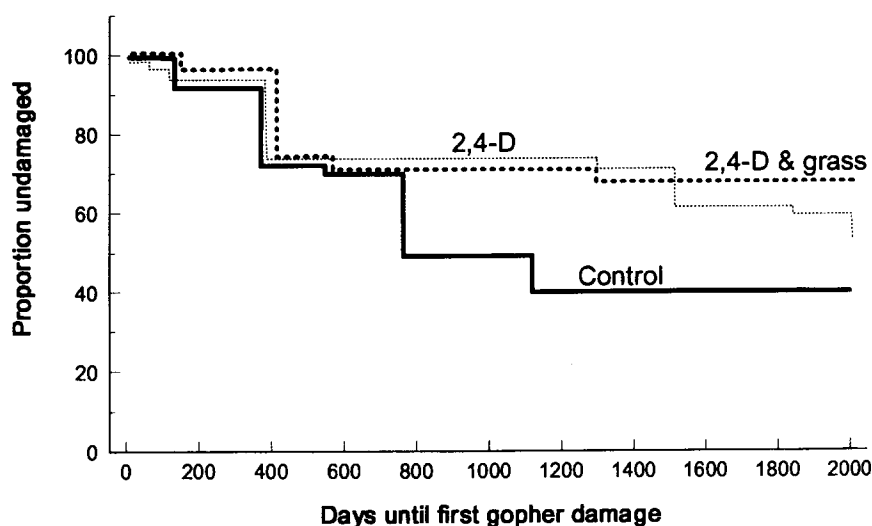


Fig. 1. Time until gopher damage for the 1973 cohort of seedlings on control, 2,4-D treated, and 2,4-D treated and grass seeding units.

from all causes (including gopher damage) presented a pattern contrary to that described for time until first gopher damage (Fig. 3). Differences among survival curves were found for the 1973 cohort, but the control seedlings displayed the greatest average survival time (Table 3), followed by the seedlings on the 2,4-D plus grass unit, and lastly, those on the 2,4-D unit (Wilcoxon comparison of survival curves;  $\chi^2 = 11.08$ ,  $df = 2$ ,  $p < 0.0039$ ). In contrast, the pattern among the units presented for the 1974 cohort survival data was similar to the 1974 cohort data for the time until first gopher damage (Fig. 4). The 2,4-D plus grass unit had the greatest survival, followed by the 2,4-D unit, with the control unit having the shortest survival times (Table 3). These survival curves were distinctly different (Wilcoxon comparison of survival curves;  $\chi^2 = 33.66$ ,  $df = 2$ ,

$p < 0.0001$ ). In the previous analyses on time until first gopher attack, seedlings dying from causes other than gopher damage were considered censored observations (withdrawn from the study at the point of death), whereas in these analyses death from all causes is used as an endpoint. Therefore, mean survival times are less than the mean times until gopher damage.

The percent growth between 1976 and 1978 was compared among units for both cohorts. Differences were found among the units for the 1973 cohort ( $F = 5.27$ ,  $df = 2, 198$ ,  $p = 0.0059$ ). Application of Duncan's multiple range test at an experiment-wise error rate of 0.05 indicated that the mean percent growth for the 2,4-D unit (138.4%) that was greater than that on 2,4-D plus grass unit (111.1%) and the control unit (107.5%). No differences ( $F = 1.15$ ,  $df = 2, 93$ ,  $p = 0.320$ ) were detected

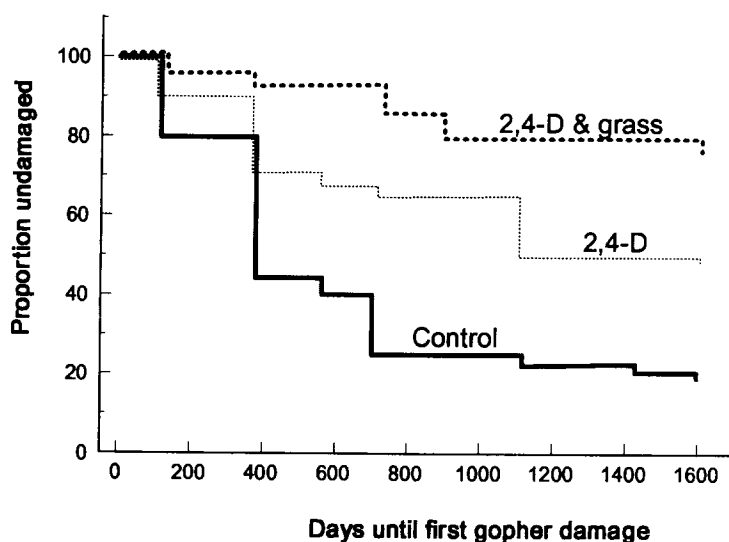


Fig. 2. Time until gopher damage for the 1974 cohort of seedlings on control, 2,4-D treated, and 2,4-D treated and grass seeding units.

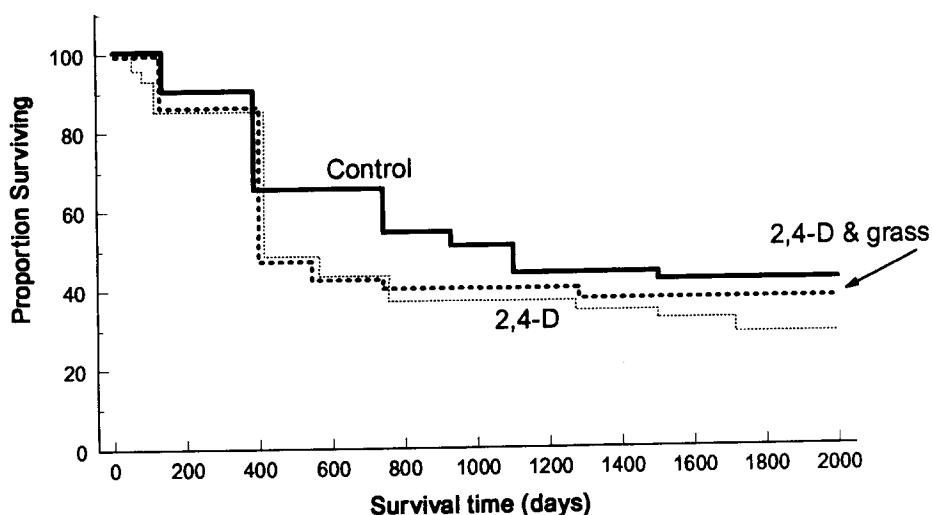


Fig. 3. Survival time for the 1973 cohort of seedlings on control, 2,4-D treated, and 2,4-D treated and grass seeding units.

among the mean percent growths for the units in the 1974 cohort (115.3%, 105.7%, and 129.3% for the 2,4-D, 2,4-D + grass, and control units, respectively).

#### 4. Discussion

For the 1973 cohort, an apparent contradiction occurred between the results for time until first gopher damage and survival times. The control unit exhibited greater damage rates than the treatment units, but it exhibited greater survival rates. The 1974 cohort produced results that were consistent between the time until first gopher damage and survival times. Those results followed what would be hypothesized with control, 2,4-D, and 2,4-D + grass presenting times until gopher damage and survival times in ascending order. Probably the

1973 cohort was affected by the operational herbicide spray and/or the follow-up spot treatment drifted onto the seedlings causing mortality. Otherwise, the 1973 cohort seedlings that were not killed from other causes on the treatment plots had lower gopher damage rates and greater survival times than the control unit seedlings. Perhaps the presence of seedlings already in the ground while forb density declined from the herbicide treatment promoted some gopher damage to seedlings, thus limiting the potential magnitude of the treatment effects.

Keith et al. (1959) demonstrated that 2,4-D applications in Colorado rangelands resulted in a virtual elimination of forbs, followed by a reduction in gopher numbers in succeeding years. Declines in pocket gopher populations after herbicide treatments have also been reported by Howard and Childs (1959); Hull (1971); Sullivan and Hogue (1987) and by Engeman et al.

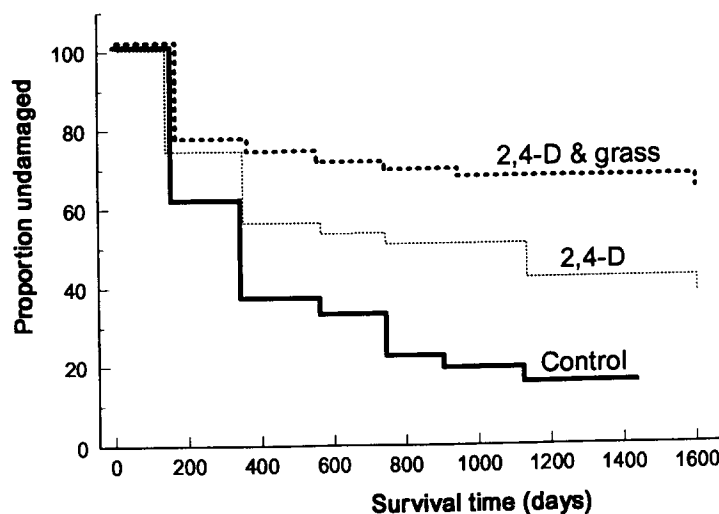


Fig. 4. Survival time for the 1974 cohort of seedlings on control, 2,4-D treated, and 2,4-D treated and grass seeding units.

(1995b). The present study did not provide definitive evidence of reduced pocket gopher activity from either of the treatments, although the tendency was for lesser amounts of activity on the treated plots. Even considering any inherent differences that may have existed among plots pre-treatment, gopher activity persisted through the course of the study on all 3 units. In a previous study in another habitat situation (Engeman et al., 1997), we found significant suppression of pocket gopher populations through 2,4-D application. We can only speculate as to the basis for our not demonstrating as strong results as some of the other herbicide studies. The Bear Springs site used in this study had a more complex vegetation community than the sites used by Engeman et al. (1995a,b, 1997) and allowed for a greater likelihood that plant species suitable as gopher forage were not adequately diminished by the treatments. It appeared, however, that the gopher populations may have been affected to a greater extent than the activity measurements suggested, since there were notable differences in the times until first gopher damage between the two treated units and the control unit for both cohorts. Perhaps a more sensitive activity/abundance index for gopher populations would have permitted such an effect to be demonstrated (Engeman et al., 1991).

Cristensen et al. (1974) and Crouch and Hafenstein (1977) reported improved stocking rates of pine seedlings following atrazine treatments. Similarly, Engeman et al. (1995b) described increased seedling survival and increased times until first gopher damage following Atrazine application. Our study suggests that 2,4-D treatment and, moreover, 2,4-D applied after grass seeding may raise the length of time on average before seedlings incur gopher damage. The 2,4-D must be applied such that seedling mortality is avoided. Timing of planting for seedlings should allow sufficient time that they would not suffer from residual effects of the herbicide. On the other hand, seedlings must be planted before vegetation (and, hence, the pocket gopher populations) recover. The vegetation can compete with seedlings while improving the habitat for pocket gophers. Seeding with grasses seemed to enhance this effect of forb removal, although we do not have enough information to indicate whether this improvement is great enough to be cost effective on an operational basis. Additional testing needs to be done to resolve these questions and questions about applications in other habitats, areas where other species of pocket gopher occur, where other species of seedlings are planted, or even if grass seeding might produce competition with seedlings in some marginal growing conditions. An understanding of the forage of the pocket gophers and the species composition of the plant community in the area to be treated will be valuable for targeting plants vital to pocket gopher populations and choosing an effective vegetative management approach.

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## References

- Acord, B.R., 1992. Responses of the ADC program to changing American society. In: Borrecco J.E., Marsh, R.E. (Eds.), Proc. 15th Vert. Pest Conf., pp. 9–16. Univ. California, Davis.
- Anthony, R.M., Barnes Jr., V.G., 1984. Plot occupancy for indicating pocket gopher abundance and conifer damage. In: Kaukeinen, D.E. (Ed.), Vertebrate Pest Control and Management Materials: Fourth Symposium, ASTM STP 817, pp. 247–255. American Society for Testing and Materials, Philadelphia.
- Barnes Jr., V.G., 1973. Pocket gophers and reforestation in the Pacific Northwest: a problem analysis. Special Scientific Report-Wildlife No. 155, USDI Fish and Wildlife Service, Washington, D.C.
- Barnes Jr., V.G., 1974. Response of pocket gopher populations to silvicultural practices in central Oregon. In: Black, H.C. (Ed.), Wildlife and Forest Management in the Pacific Northwest, pp. 167–175. Oregon State Univ.
- Black, H.C., Hooven, E., 1977. Effects of herbicide-induced habitat changes on pocket gophers in southwestern Oregon. Report of the 29th Annual California Weed Conference, Sacramento, pp. 119–127.
- Burton, D.H., Black, H.C., 1978. Feeding habits of Mazama pocket gophers in south-central Oregon. J. Wildl. Manage. 42, 383–390.
- Campbell, D.L., Farley, J.P., Hegdal, P.L., Engeman, R.M., Krupa, H.W., 1992. Field efficacy evaluation of diphacinone paraffin bait blocks and strychnine oat groats for control of forest pocket gophers (*Thomomys* spp.). In: Borrecco J.E., Marsh, R.E. (Eds.), Proc. 15th Vert. Pest Conf., pp. 299–302. Univ. California, Davis.
- Cristensen, M.D., Young, J.A., Evans, R.A., 1974. Control of annual grasses and revegetation in the ponderosa pine woodlands. J. Range Manag. 27, 143–145.
- Crouch, G.L., 1979. Atrazine improves survival and growth of ponderosa pine threatened by vegetative competition and pocket gophers. Forest Sci. 25, 99–111.
- Crouch, G.L., 1986. Pocket gopher damage to conifers in western forests: a historical and current perspective on the problem and its control. In: Salmon, T. (Ed.), Proc. 12th Vert. Pest Conf., pp. 196–198. Univ. California, Davis.
- Crouch, G.L., Franks, L.R., 1979. Poisoning and trapping pocket gophers to protect conifers in northeastern Oregon. USDA Forest Service Research Note, Pacific North West Forest and Range Experiment Station, Portland, OR. PNW-261.
- Crouch, G.L., Hafenstein, E., 1977. Atrazine promotes ponderosa pine regeneration. USDA Forest Service Research Note, Pacific North West Forest and Range Experiment Station, Portland, OR. PNW-309.
- Daubenmire, R., 1959. A canopy-coverage method of vegetational analysis. North West Science. 33, 43–64.
- Engeman, R.M., Campbell, D.L., Evans, J., 1991. An evaluation of two activity indicators for use in mountain beaver (*Aplodontia rufa*) burrow systems. Wildlife Society Bulletin. 19, 413–416.
- Engeman, R.M., Campbell, D.L., Nolte, D., Witmer, G., 1995a. Some recent research results on non-lethal means for reducing animal

- damage to reforestation projects in the western United States. In: Statham, M. (Ed.), 10th Australian Vertebrate Pest Control Conference, Vol. 10, pp. 150–154.
- Engeman, R.M., Barnes, V., Anthony, R.M., Krupa, H.W., 1995. Vegetative management for reducing damage to ponderosa pine seedlings from *Mazama* pocket gophers. *Crop Protection*, 14, 505–508.
- Engeman, R.M., Barnes, V., Anthony, R.M., Krupa, H.W., 1997. Effect of vegetation management for reducing damage to lodgepole pine seedlings from northern pocket gophers, Vol. 16, pp. 407–410.
- Hansson, L., 1975. Effects of habitat manipulation on small rodent populations. In: Hansson, L., Nilsson, B. (Eds.), *Biocontrol of Rodents*, pp. 163–173. Swedish Nat. Res. Council, Stockholm.
- Howard, W.E., Childs, H.E., 1959. Ecology of pocket gophers with emphasis on *Thomomys bottae mewa*. *Hilgardia*, 29, 277–358.
- Hull, A.C. Jr., 1971. Effects of spraying with 2,4-D on abundance of pocket gophers in Franklin Basin, Idaho. *J. Range Manage.* 24, 230–232.
- Kalbfleish, J.D., Prentice, R.L., 1980. *The Statistical Analysis of Failure Time Data*, p. 321. John Wiley and Sons, New York.
- Kaplan, E.L., Meier, P., 1958. Nonparametric estimation from incomplete observations. *J. Amer. Stat. Assoc.* 53, 457–481.
- Keith, J.O., Hansen, R.M., Ward, A.L., 1959. Effect of 2,4-D on abundance and foods of pocket gophers. *J. Wildl. Manage.* 23, 137–145.
- Sullivan, T.P., 1986. Understanding the resiliency of small mammals to population reduction: poison or population dynamics? In: Richards, C.G.J., Ku, T.Y. (Eds.), *Control of Mammal Pests*, pp. 69–82. Taylor and Francis Ltd., London. (Suppl. to *Tropical Pest Mgt.* 32, 69–82.).
- Sullivan, T.P., Hogue, E.J., 1987. Influence of orchard floor management on vole and pocket gopher populations and damage in apple orchards. *J. Am. Soc. Hort. Sci.* 112, 972–977.
- Tietjen, H.P., Halvorsen, C.H., Hegdal, P.L., Johnson A.M., 1967. 2,4-D herbicide, vegetation, and pocket gopher relationships, Black Mesa, Colorado. *Ecology*, 48, 634–643.
- Volland, L.A., 1976. Plant communities of the central Oregon pumice zone. USDA For. Serv. Pac. Northwest Reg. R-6 Area Guide 4 2, p. 110.